4th Day

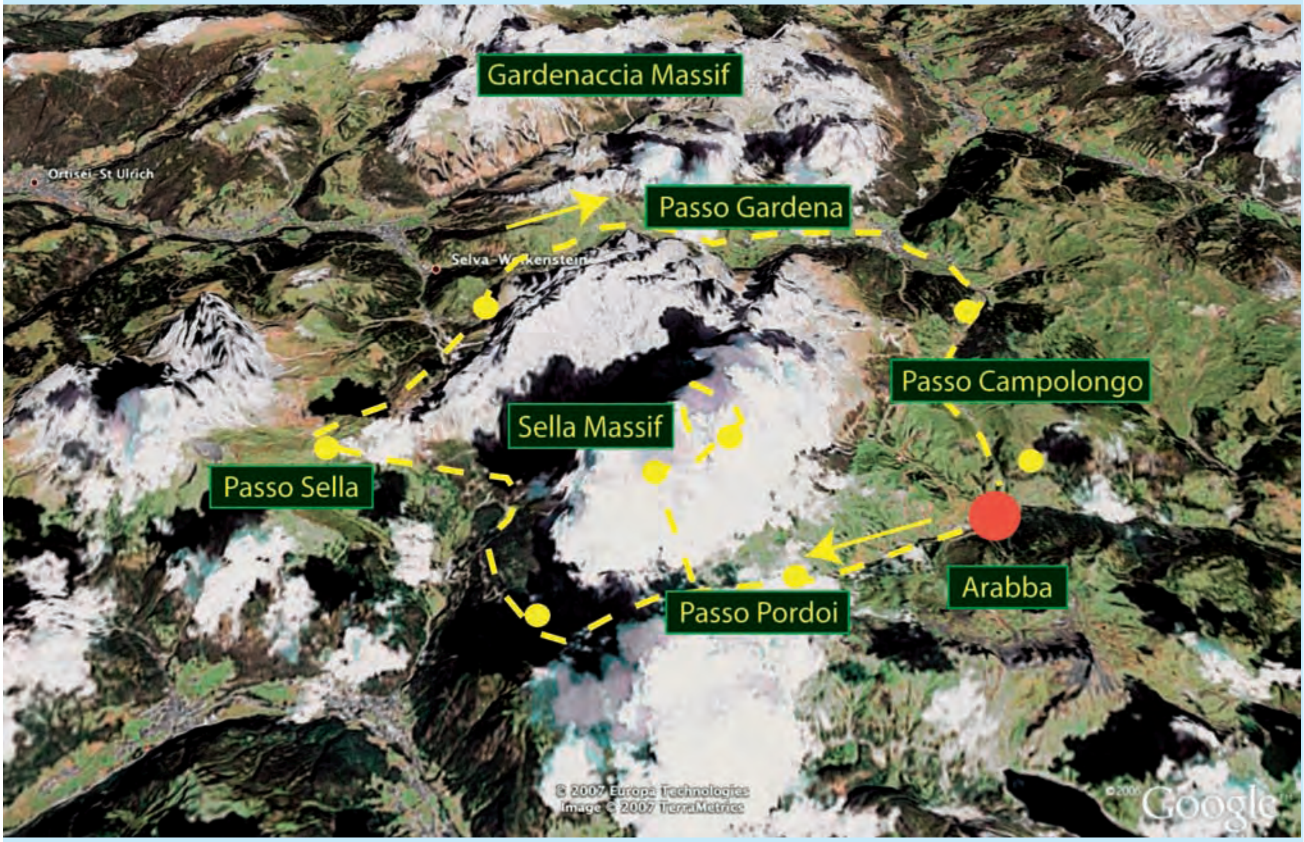


Fig. 4.0 - Itinerary: Sella massif, Piz Boè

Subject: Analysis of a thrust; Mesozoic architecture.

This day is entirely dedicated to the geology of the Sella Massif, at the heart of the Dolomites, in the core of the large basement syncline where the sedimentary cover crops out. The Sella Massif is probably one of the most fascinating mountains from the geological point of view. The quality and quantity of geological observations is extraordinary: the geometry of the Carnian carbonate platform that forms the basal portion of the massif that radially progrades from the internal lagoon to the adjacent basin of the San Cassiano Fm; the effects of compaction on the basinal deposits; the geometries of the beautifully exposed thrust of the Piz Boè; the control of stratigraphic architecture on tectonics and synsedimentary faults.
The peak thrust of the Piz Boè is located at the front of the W-SW vergent thrust system of the central-western Dolomites, that can be regionally related to the Dinaric belt, or to an alpine oblique ramp associated to the transfer between a recess and a salient. It is possible to analyze the thrust architecture in three dimensions, observing the lateral ramps connecting decollement planes and frontal ramps.

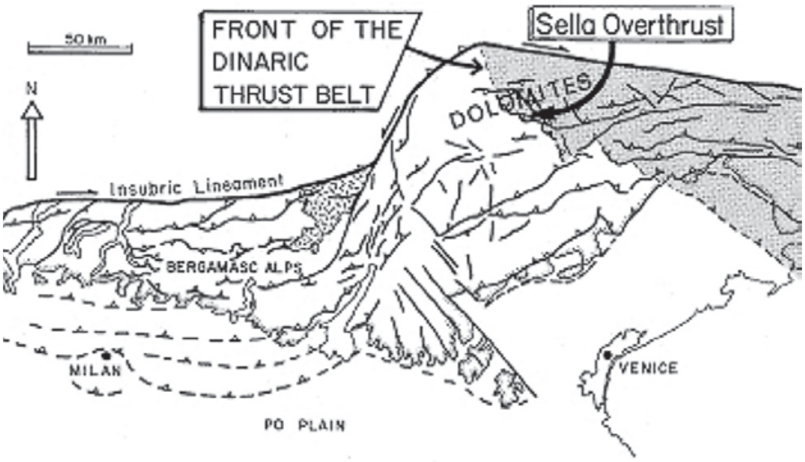


Fig. 4.1 - The Sella thrust might represent the front of the WSW-vergent Dinaric fold and thrust belt, of Paleogene-Lower Neogene age. The front of the Dinarides cuts obliquely the eastern Southern Alps and was dissected by later (Neogene) southalpine thrusts. Alternatively, the WSW-vergent thrusts in the Dolomites, as discussed earlier, could represent an earlier Alpine right-lateral undulation along the eastern margin of the Trento Horst, conjugate to the left-lateral transpression along the Giudicarie belt, emplaced along the western margin of the Trento Horst.

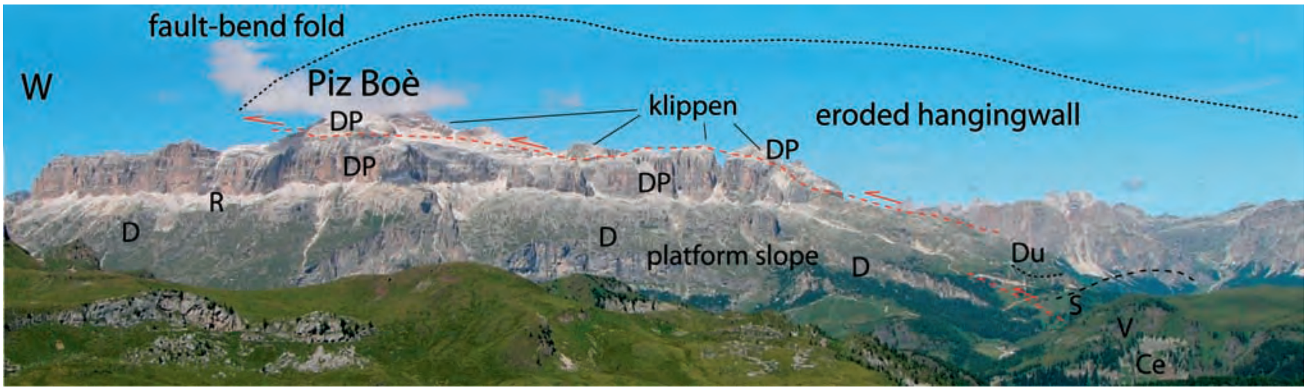


Fig. 4.2 - View of the Sella Massif from the south. The basal part consists of Cassian Dolomite (D) of Middle Carnian age. The overlying debris in the middle consists of rocks belonging to the Upper Carnian Raibl Fm (R). The upper cliff is made of Norian Dolomia Principale (DP). Du, Dürrenstein Dolomite, S, San Cassiano Fm; V, Volcanoclastic sandstones; Ce, Caotico Eterogeneo. The thrust followed the shape of the Carnian platform slope, it continued in ramp into the Dolomia Principale, and with a staircase trajectory arrived at the top of the Piz Boè with its classic summit klippe geometry. The top klippe overlies a condensed Jurassic-Cretaceous succession.

Fig. 4.3 - Val Lasties, looking to the west from the Sella Massif. Beyond the Sella Massif, the Sassolungo Massif can be recognized. Observing the right flank of the valley, the basal cliff is still constituted by upper Cassian Dolomite (CD), the gentle slope by Raibl Fm (R) and the upper cliff by Dolomia Principale (P). Note that the Raibl Fm thickens moving away from the platform: at the outermost peak of the Sella Massif (Piz Ciavaces), the Raibl Fm is some 80 m thick, whereas it dies out at the core of the Sella Massif. The Sella plateau, like other Dolomitic massifs is characterized by large fossil erosional terraces that according to Rossi (1957) could be related to an Oligocene erosional surface.

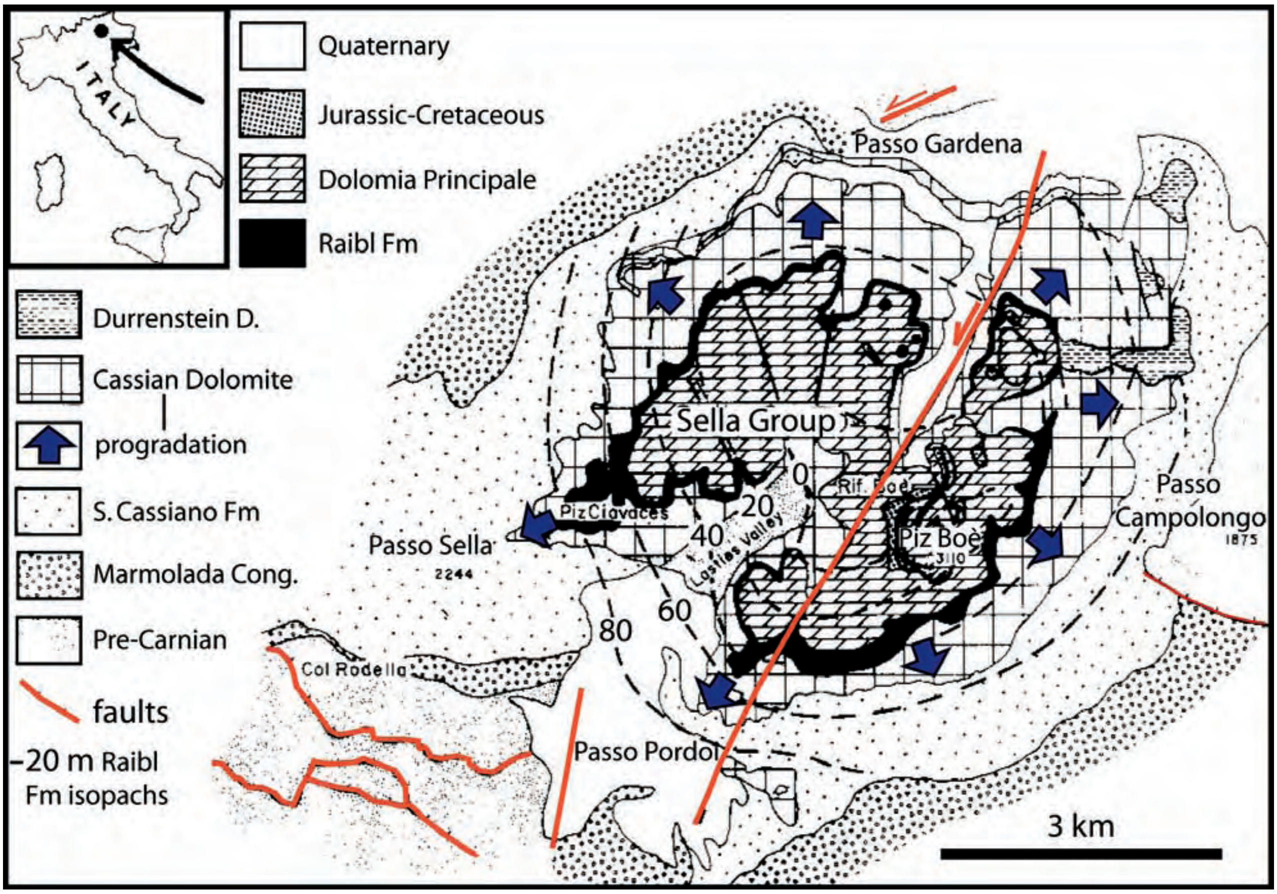


Fig. 4.4 - Geological map of the Sella Group. Notice the radial progradation of the Carnian carbonate platform (Cassian Dolomite). The Sella group is a perfectly preserved atoll (Leonardi, 1967). The isopachs of the Raibl Fm indicate a thickening of the formation away from the Carnian platform. This suggests a relationship between the geometry of the Raibl Fm deposits and the underlying platform-basin system. To the right, south of Campolongo Pass a SSW-vergent thrust fault sutured by basinal deposits of the San Cassiano Fm can be observed (Doglioni & Goldhammer, 1988).

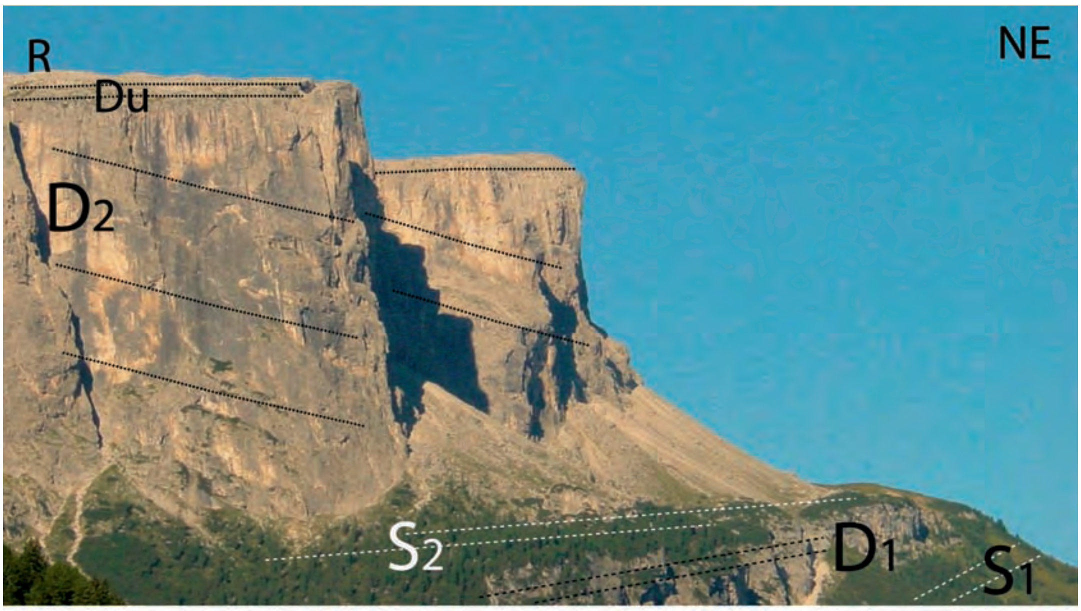


Fig. 4.5 - Northern slope of the Sella Massif, west of Corvara. The Cassian Dolomite (upper platform D2) progrades northward over the San Cassiano Fm (S2). A lower Cassian Dolomite (D1) and related basin (S1) are below. Du, Dürrenstein Dolomite, R, Raibl Fm.

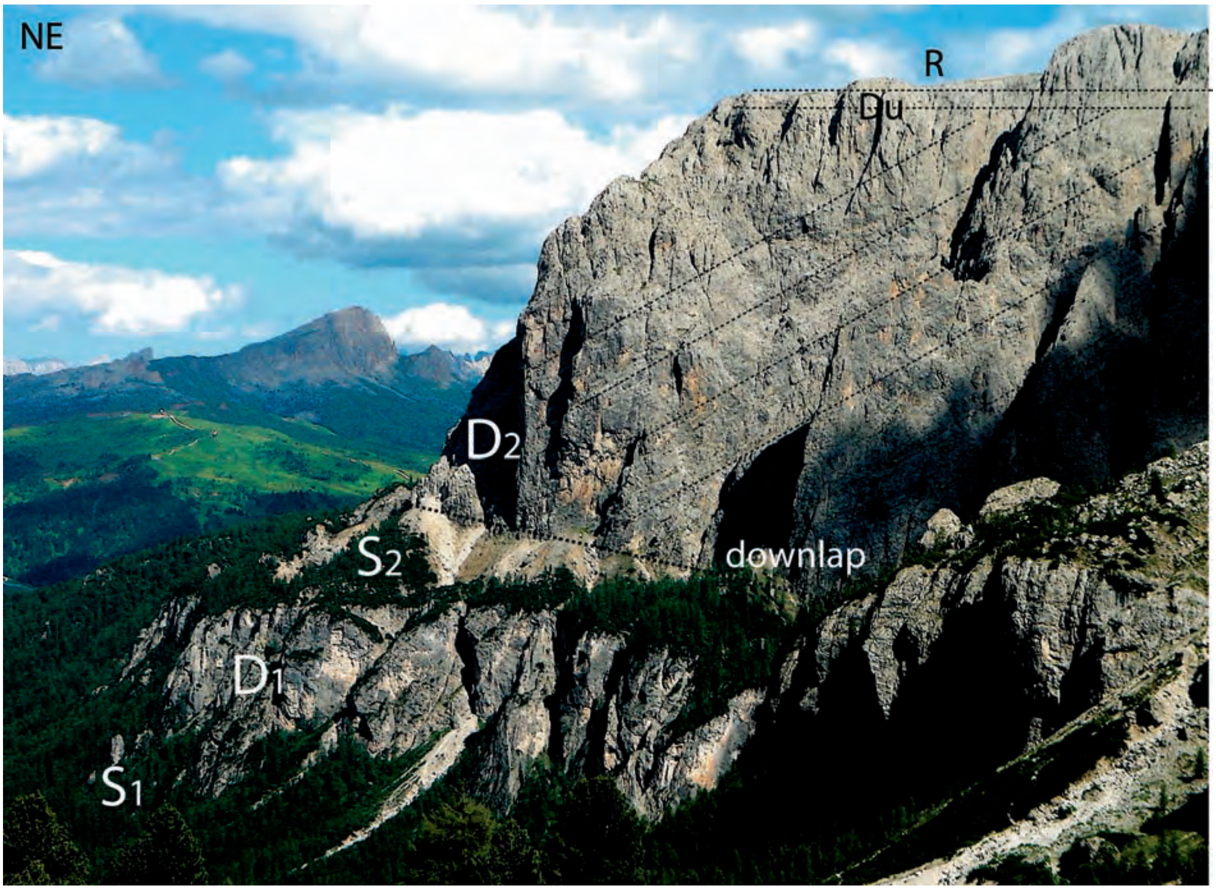


Fig. 4.6 - Northeastern slope of the Sella Massif. The Cassian Dolomite (upper platform D2) progrades northeastward over the San Cassiano Fm (S2). A lower Cassian Dolomite (D1) and related basin (S1) are below. Du, Dürrenstein Dolomite, R, Raibl Fm.

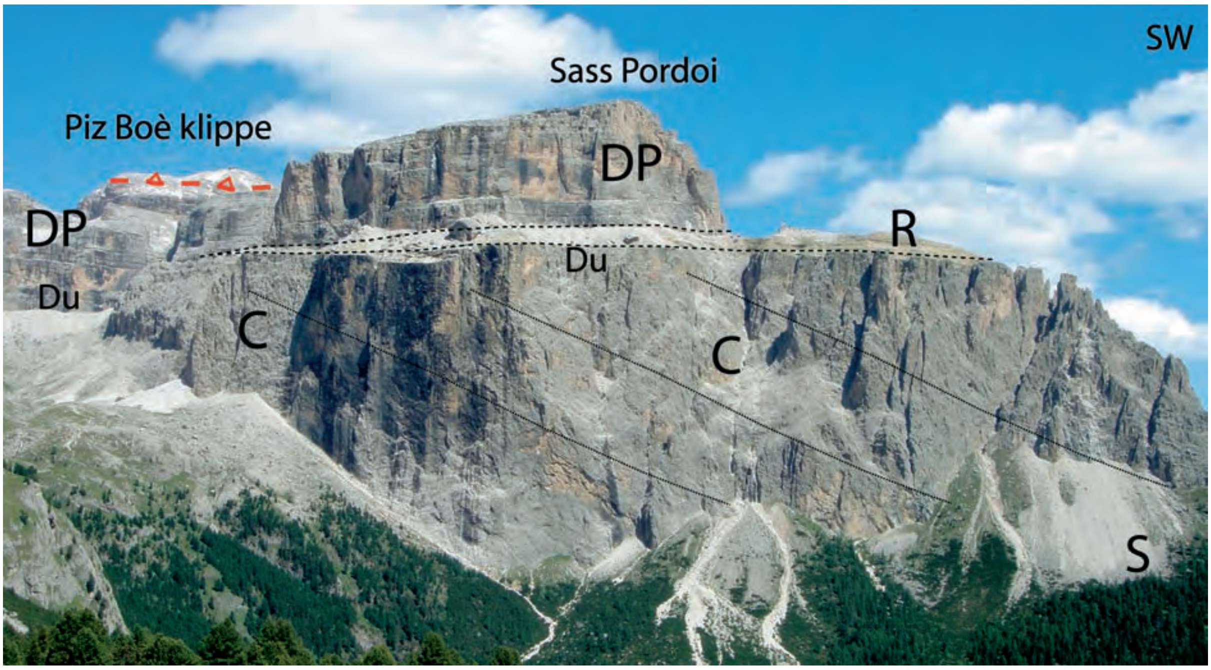


Fig. 4.7 - Southwestern margin of the Sella massif. The Carnian Cassian Dolomite (C) with its lagoon Dürrenstein Dolomite (Du) progrades over the basinal equivalent San Cassiano Fm (S). The Raibl Fm (R) above thins toward the interior of the atoll, for the larger subsidence of the platform margin over the basinal sediments. DP, Norian Dolomia Principale.

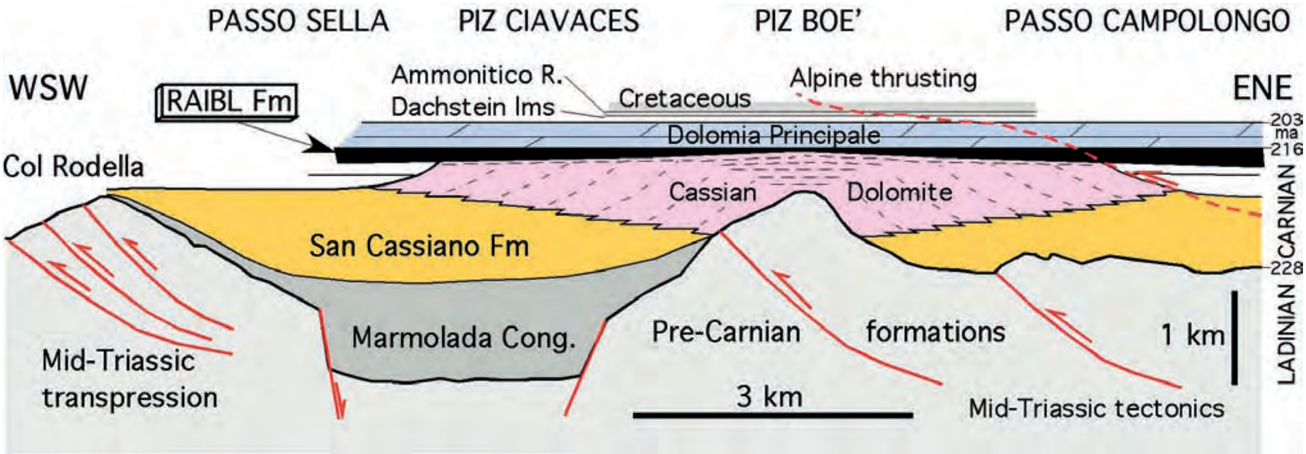
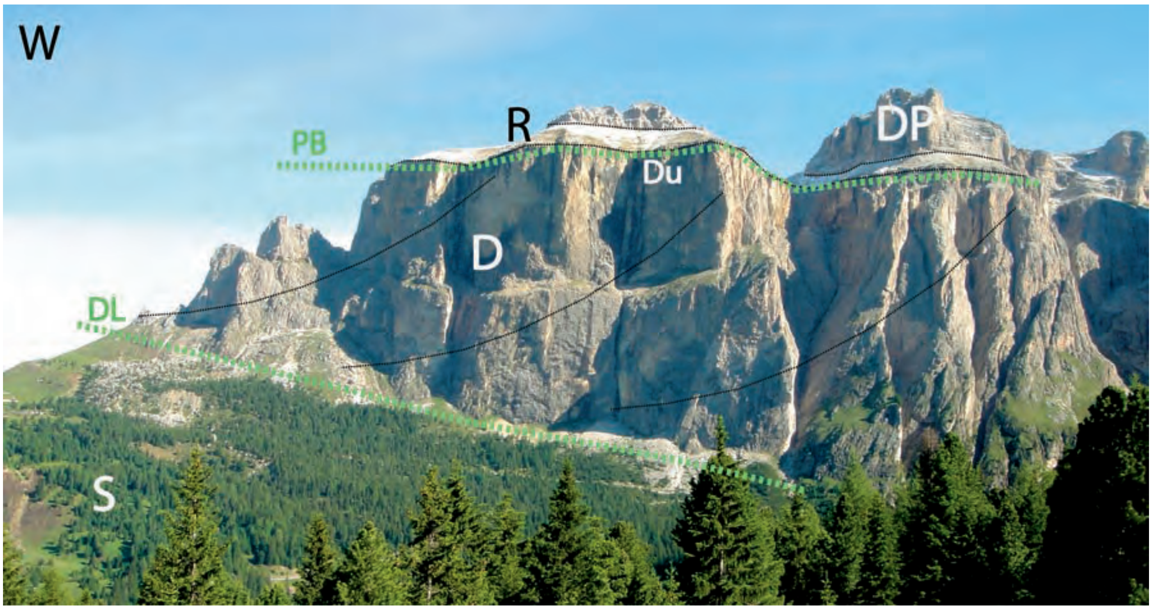
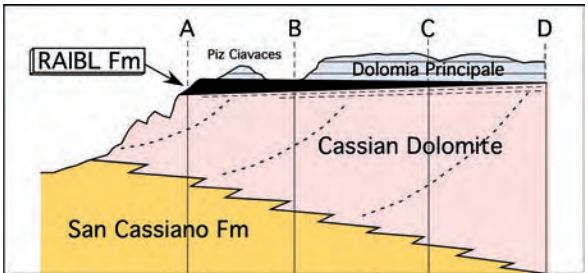


Fig. 4.8 - Geological section for the Upper Triassic through the Sella Massif. Notice the wedge shape of the Raibl Fm above the Cassian Dolomite prograding onto the San Cassiano Fm; the Raibl deposits die out in correspondance with the termination, at depth, of the basinal San Cassiano Fm. This suggests that the compaction of the Cassian basinal deposits generated the subsidence that allowed the deposition of the Raibl Fm. Notice the Triassic tectonic features buried under the Carnian formations (after Doglioni & Goldhammer, 1988).





thickness	A	B	C	D
Raibl Fm	80	50	20	0
Cassian Dolomite	380	550	700	900
San Cassiano Fm	440	320	180	0
" decompacted	515	377	207	—
" Δx	75	57	27	—

Fig. 4.9 - Photo and geological E-W section of the western margin of the Sella group, towards Passo Sella. The Raibl wedge (R) is evidenced below the the Dolomia Principale (DP). The carbonate platform of the Cassian Dolomite (D) progrades onto the basin of the San Cassiano Fm (S). Du, Dürrenstein Dolomite. The platform break surface (PB) and the downlap surface (DL) are convergent, in agreement with the shallowing upward of the San Cassiano Fm. In the panel to the right the letters indicate the sections where decompaction modelling was performed: notice that the decompaction in the basinal deposits of the San Cassiano Fm (shales, marls, calcarenites, volcaniclastic sandstones) is able to explain the ca. 2° tilt of the of the top of the Cassian carbonate platform and the magnitude of subsidence that allowed the deposition of the Raibl Fm deposits. In other words, the syn-Raibl Fm subsidence was controlled by the compaction of the basinal Cassian deposits (after Doglioni & Goldhammer, 1988).

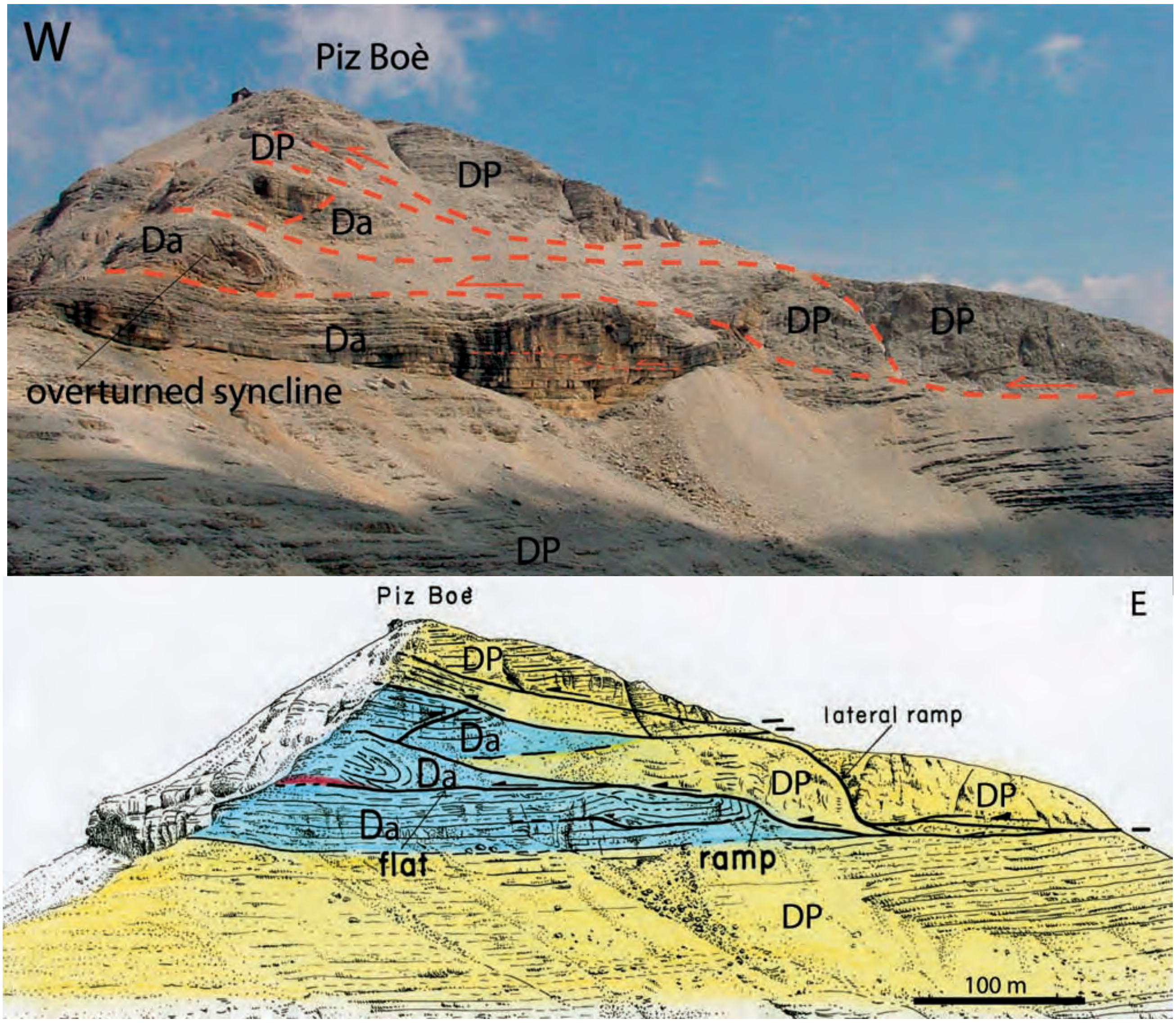
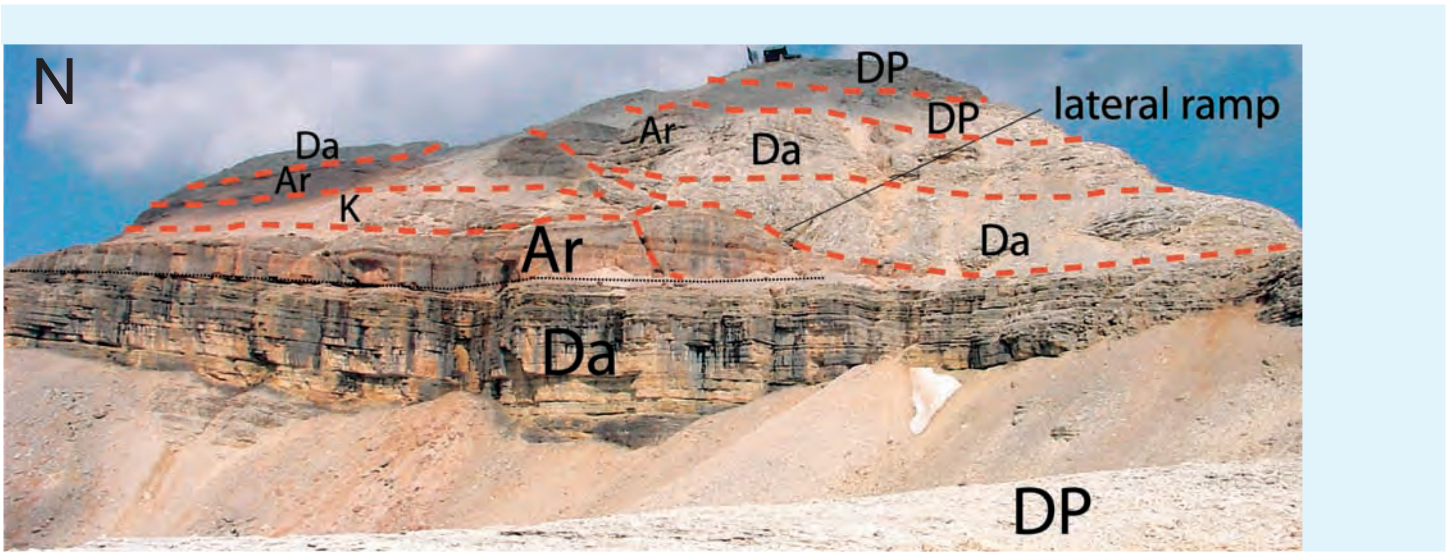


Fig. 4.10 - Southern view of the Piz Boè. The thrusts show staircase geometry with decollements at the top of the Dolomia Principale (P) and of the Dachstein Limestone (D), with connection ramps. Compare with Fig. 4.11 and Fig. 4.12 to appreciate how deformation varies along the strike of the thrust fault. Legend, DP, Dolomia Principale; Da, Dachstein Limestone (after Doglioni, 1990).



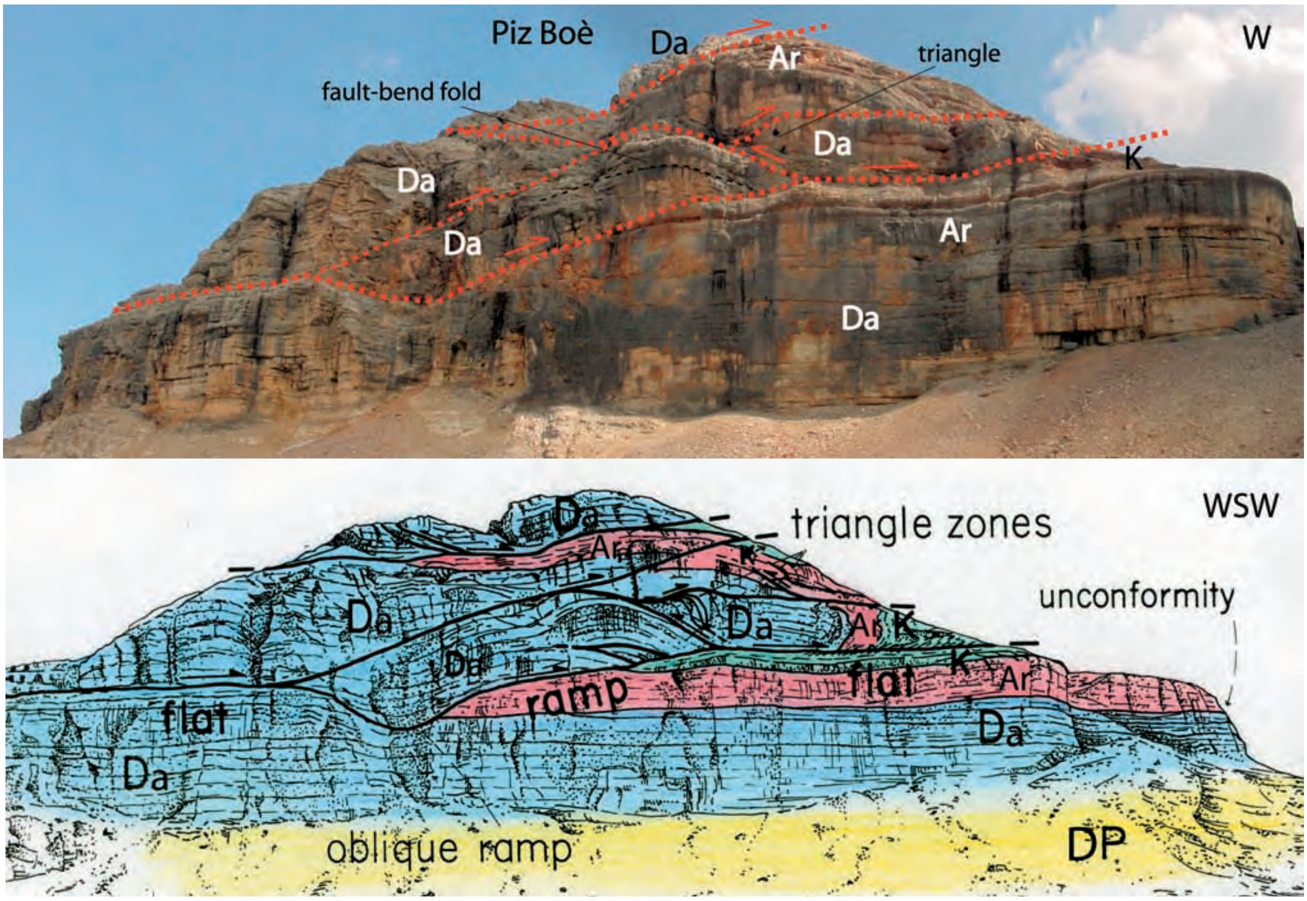


Fig. 4.11 - Northern view of the Piz Boè. Notice the various triangle structures and the ramp-flat geometry controlled by stratigraphy. The basal surface of the thrust system is stratigraphically higher with respect to the southern section of Piz Boè (Fig. 4.10). This is explained by the occurrence of an intermediate lateral ramp (Fig. 4.12). Legend, DP, Dolomia Principale, Norian; Da, Dachstein Limestone, Rhaetian; Ar, Ammonitico Rosso, M-U Jurassic; K, Puez Marls, Cretaceous (after Doglioni, 1990).

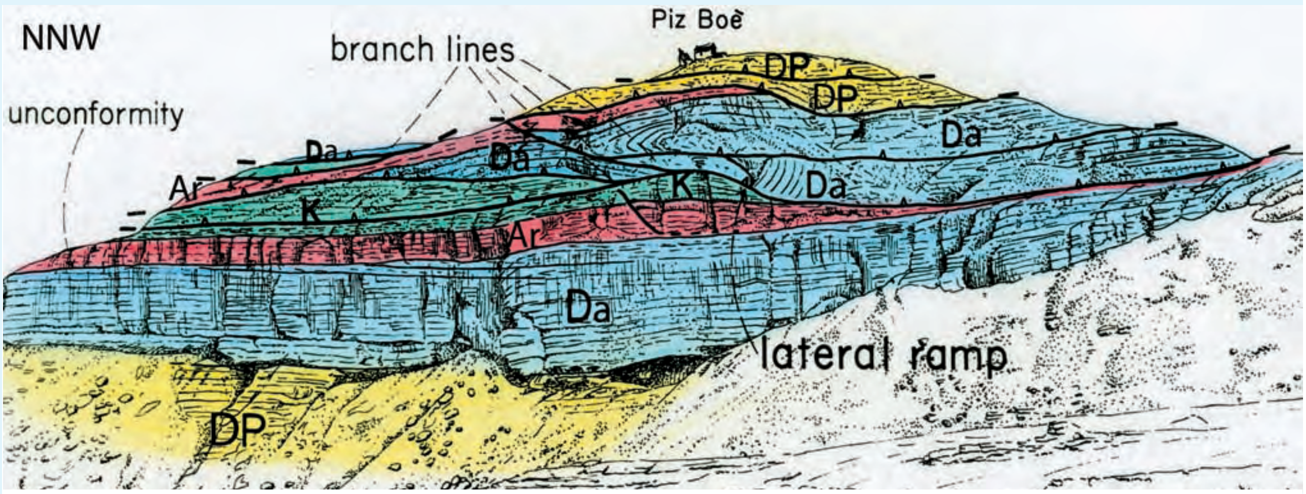


Fig. 4.12 - Western view of the Piz Boè (left front page), a natural section along the strike of the thrust system, that verges towards the observer. The structural link between the previous two sections can be observed. Notice the numerous branches and the main lateral ramp connecting the basal decollements of the northern and southern sections. There is, thus, a continuous structural variation along strike. It is interesting to notice, in the hangingwall of the lateral ramp, a fold whose axis is parallel to the transport direction. Legend, DP, Dolomia Principale; Da, Dachstein Limestone; Ar, Ammonitico Rosso; K, Puez Marls.

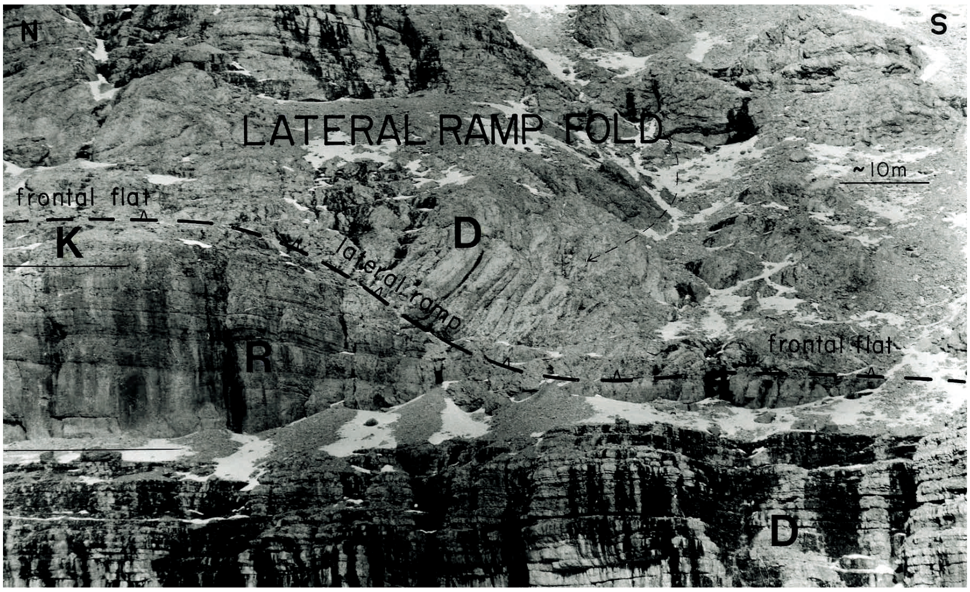


Fig. 4.13 - Detail of the lateral ramp of the previous figure, after DOGLIONI (1990).

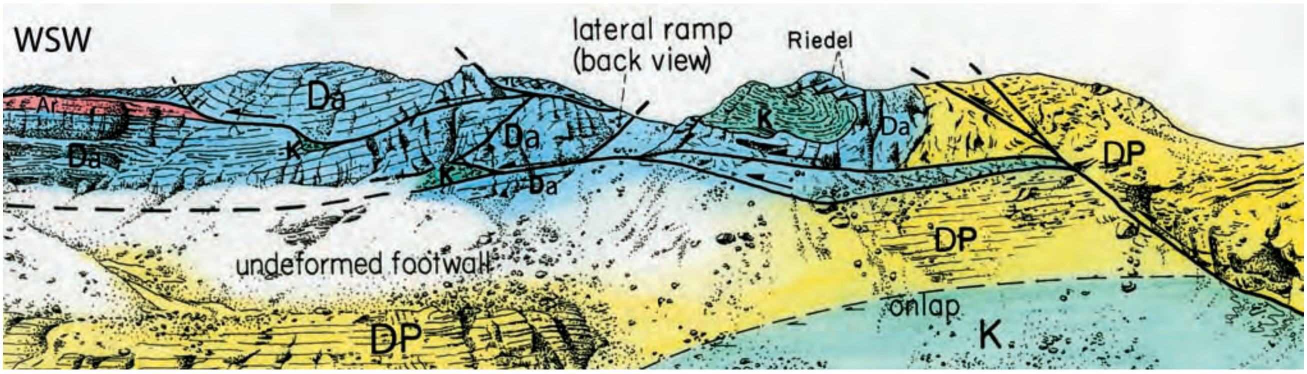


Fig. 4.14 - Eastern view of Piz Boè. Note the constant undulate trajectory of the thrust planes. At the bottom right, a deep scar in the Norian Dolomia Principale (P) is filled by the Early Cretaceous Puez Marls (K). R, Rosso Ammonitico (Middle-Late Jurassic); D, Dachstein Limestone (Rhaetian).

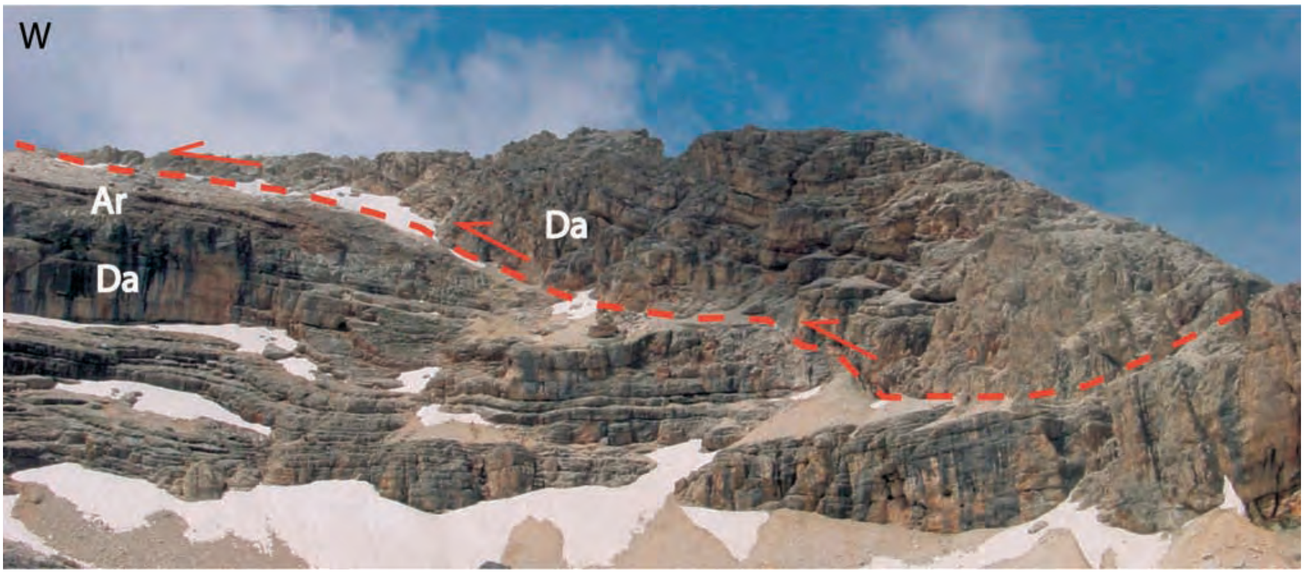


Fig. 4.15 - Detail of the left upper part of the previous drawing. The topmost thrust of the imbricate system of thrusts of the Sella Massif showing undulated geometry with ramps and flats. Da, Dachstein Limestone; Ar, Ammonitico Rosso.

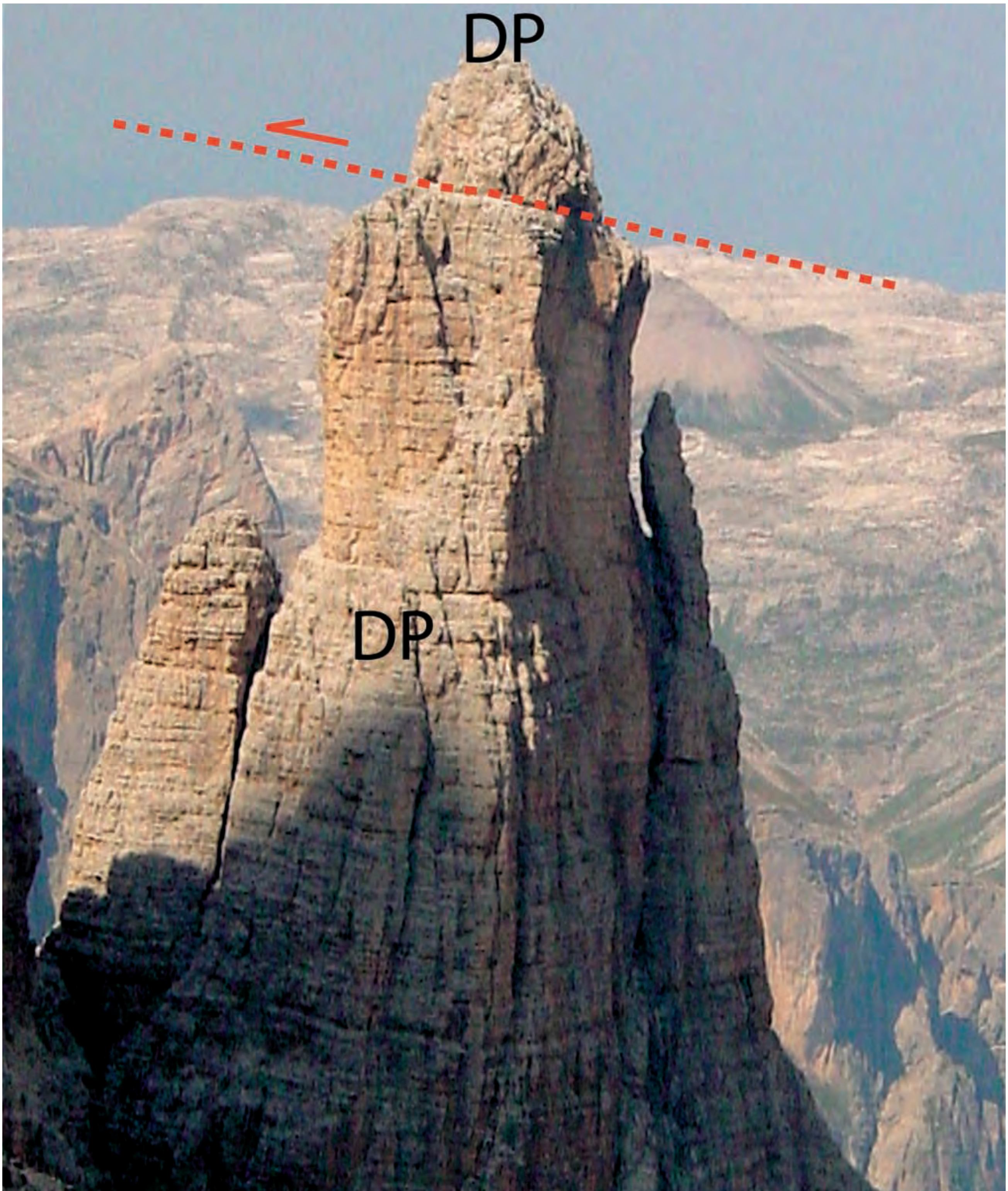


Fig. 4.16 - Classical klippe with Dolomia Principale (DP) both in the footwall and in the hangingwall of a tower located in the left flank of the Val de Mesdì, north of Piz Boè.

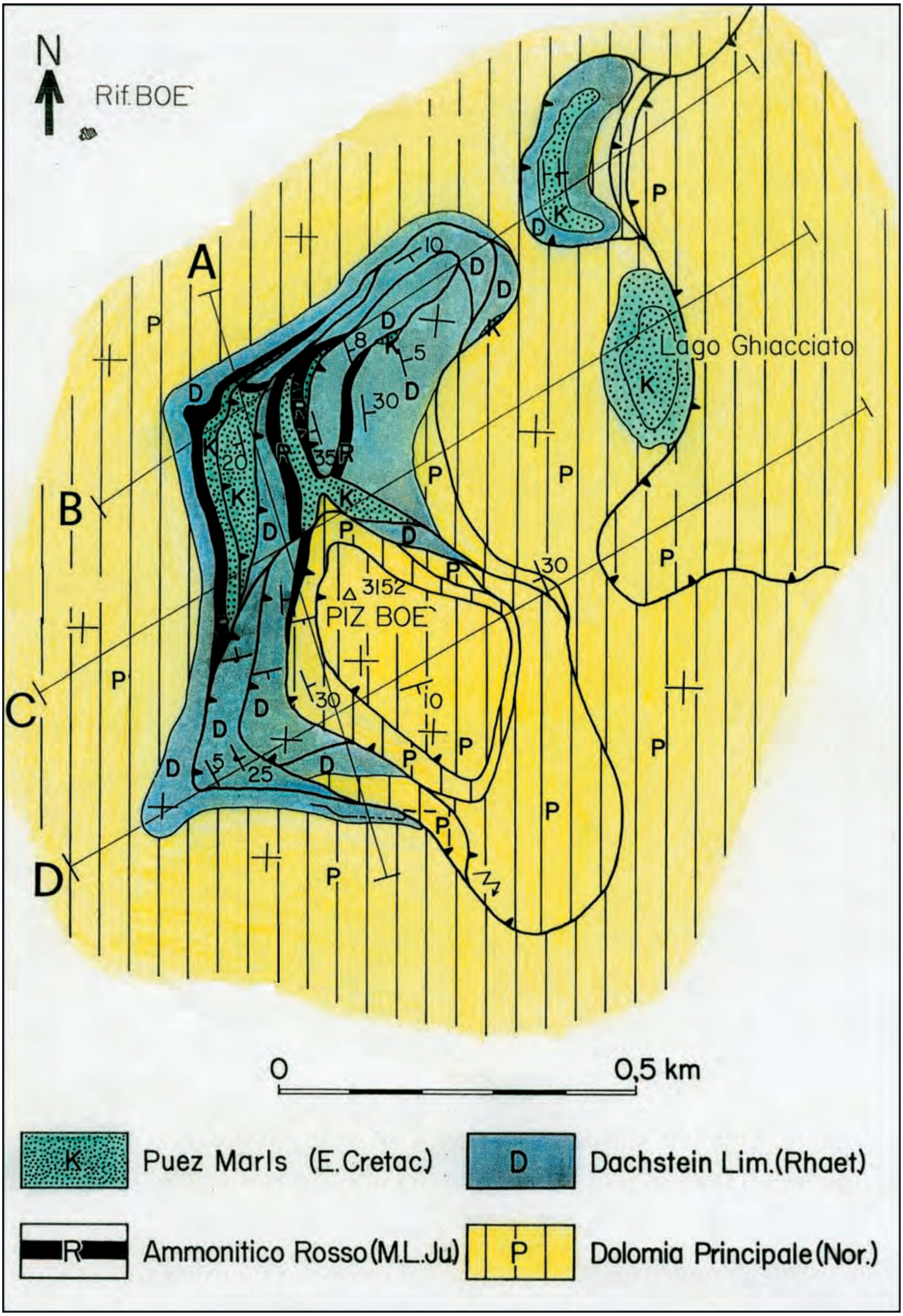


Fig. 4.17 - Geological map of Piz Boè, at the top of the Sella Massif (after DOGLIONI, 1990).

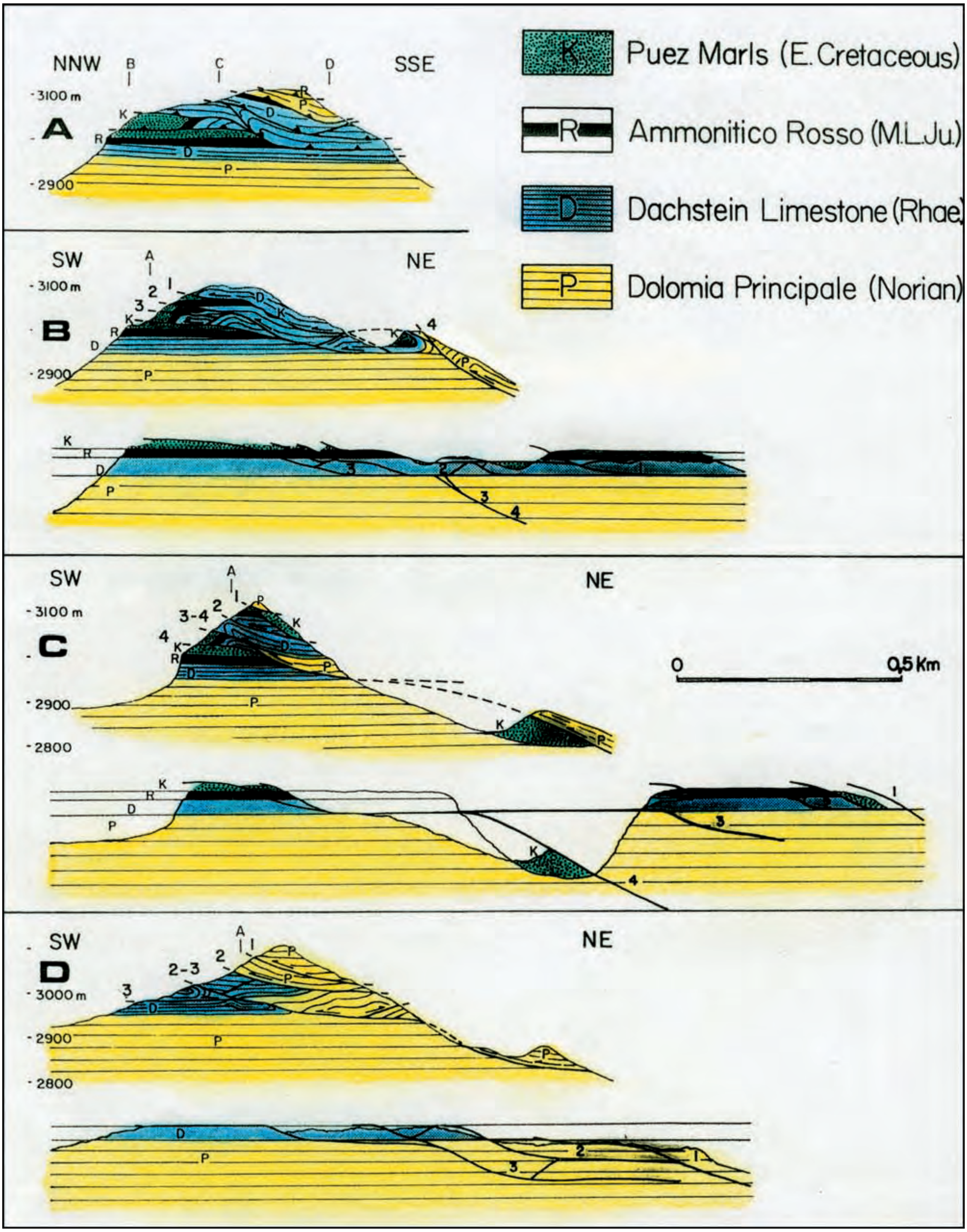


Fig. 4.18 - Geological cross sections across Piz Boè. A is a longitudinal section showing the lateral ramp and the thrust branches that allow the continuous variation of the geometries along strike. The structure is very irregular although the shortening (about 1 km) remains quite constant. The numbers indicate the reconstructed kinematics of the thrust faults. The occurrence of deep scars filled by Puez Marls explains the tectonic transport of Cretaceous sediments above older rocks (e.g., section C). The location of the cross sections is in the previous figure.

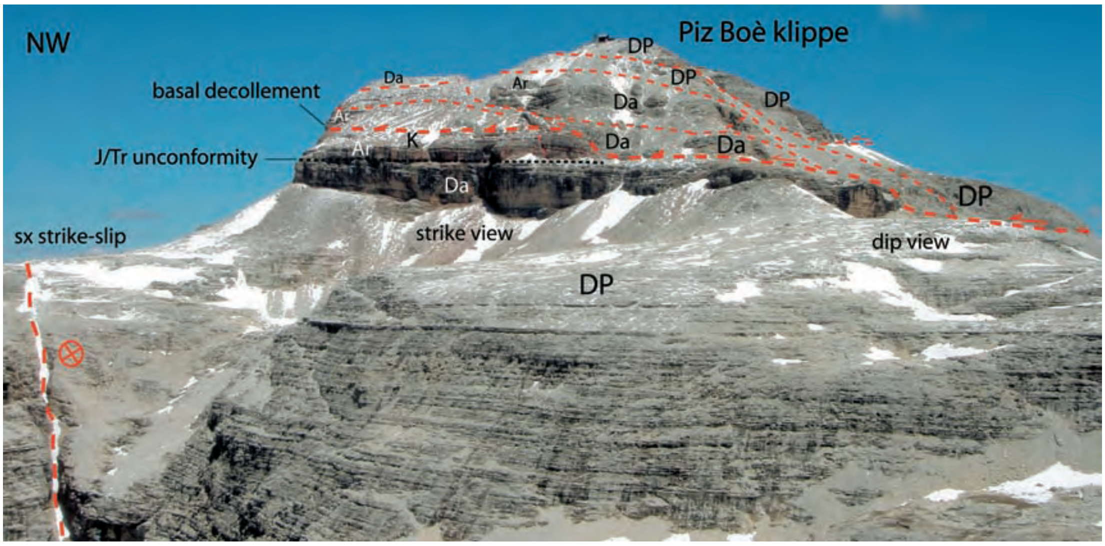


Fig. 4.19 - General view of the top of the Sella Massif, i.e., the Piz Boè with its klippe made of a stack of thrusts with small lateral continuity and a number of branch lines.

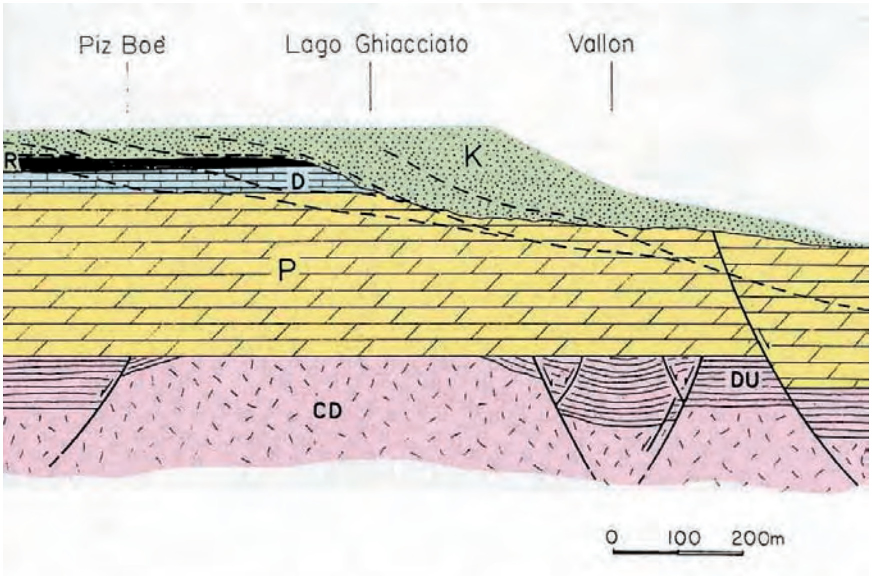


Fig. 4.20 - Stratigraphic relationships in the upper part of the Sella Massif and location of the thrust faults. Sequence boundaries are frequently detachment planes.The thrust faults cut pre-existing Mesozoic extensional faults. Notice also the Cretaceous erosional surface. CD, Cassian Dolomite (Middle Carnian); DU, Dürrenstein Dolomite (Upper Carnian); P, Dolomia Principale (Norian); D, Dachstein Limestone (Rhetian); R, Ammonitico Rosso (Middle-Upper Jurassic); K, Puez Marls (Lower Cretaceous).

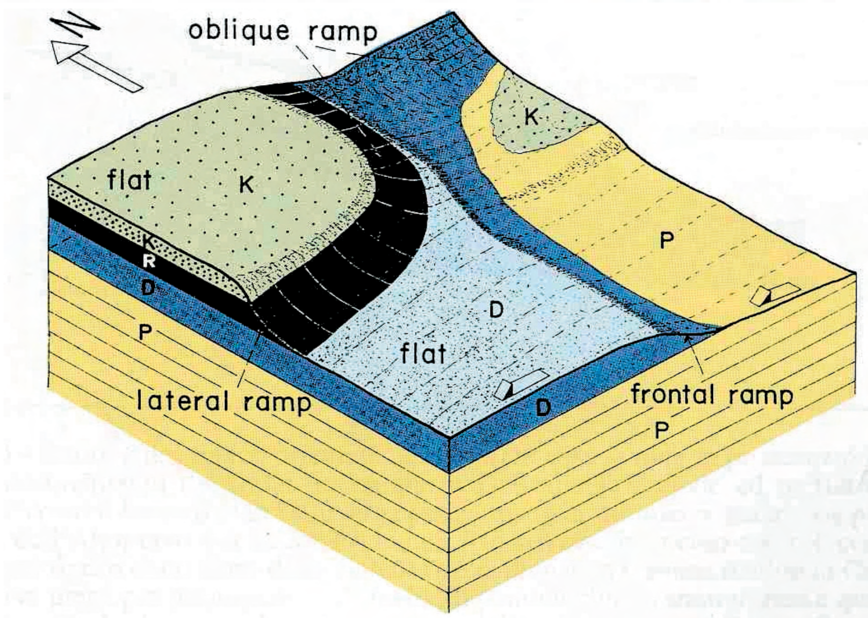


Fig. 4.21 - Geometry of the basal detachment surface of the Sella thrust. P, Dolomia Principale; D, Dachstein Limestone; R, Ammonitico Rosso; K, Puez Marls (after Doglioni, 1990).

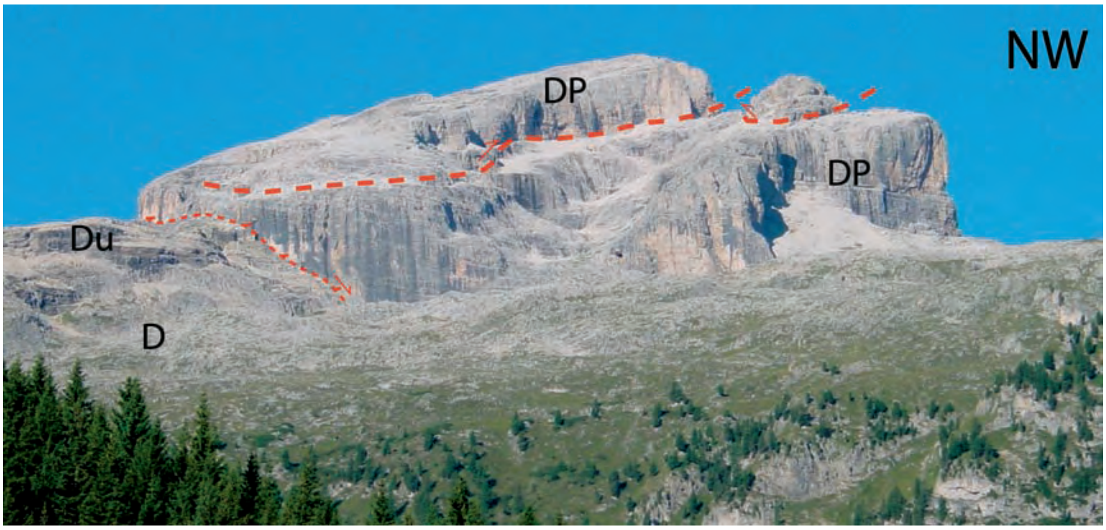


Fig. 4.22 - Eastern ramp of the Sella Thrust, where two klippen of Dolomia Principale (DP) crop out in the northeastern part of the massif. View from the road between Corvara and the Campolongo Pass. Du, Dürrenstein Dolomite; D, Cassian Dolomite.

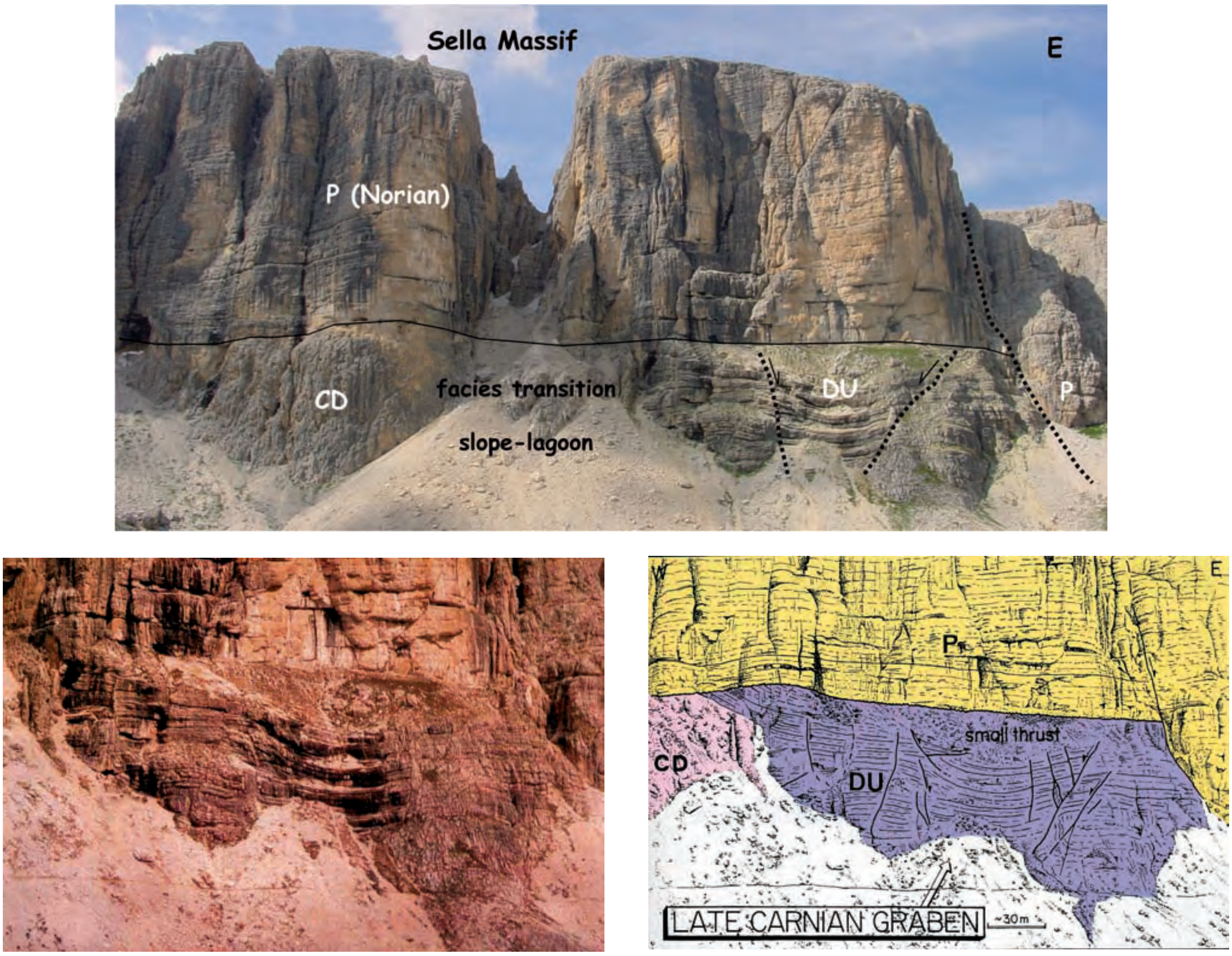


Fig. 4.23 - In the Vallon del Serla (Serla canyon), east of Piz Boè, an Upper Carnian N-S oriented graben, sealed by the Dolomia Principale, crops out undeformed in the footwall of the Sella thrust. P, Dolomia Principale (Norian) above the unconformity; DU, Dürrenstein Dolomite; CD, Cassian Dolomite.

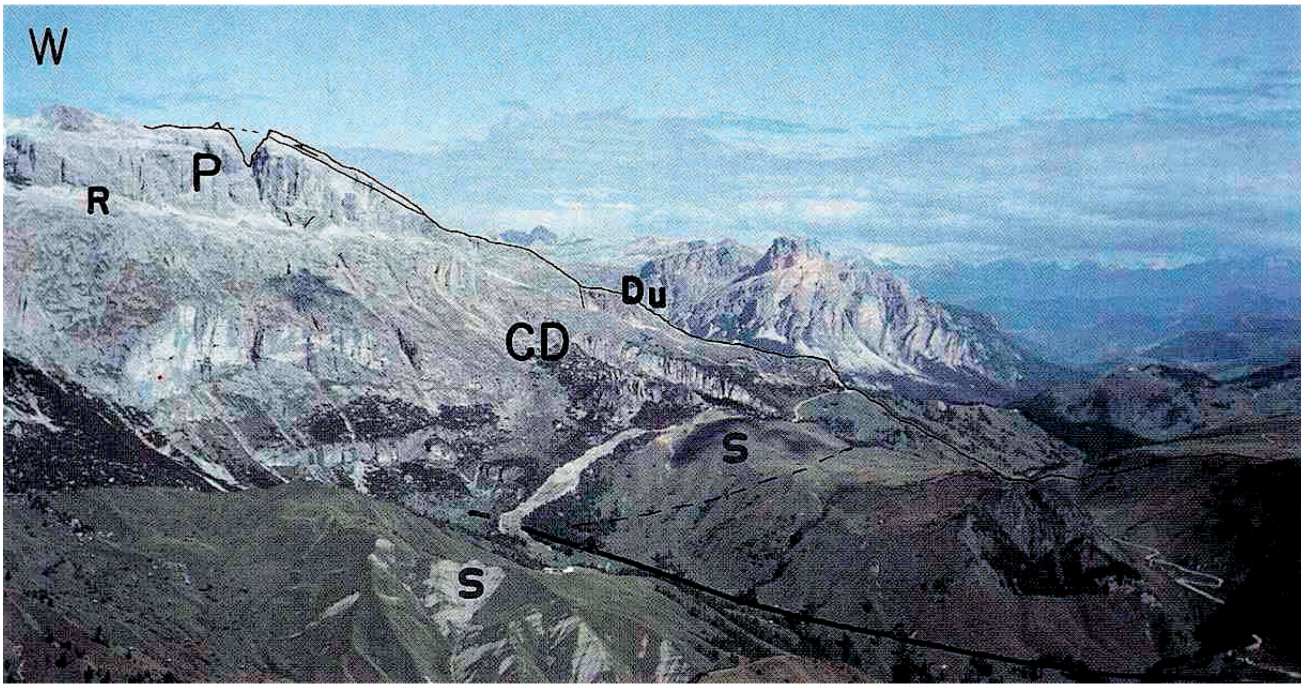


Fig. 4.24 - Eastern flank of the Sella Group and Campolongo Pass. The black profile shows the trace of the section of Fig. 4.25. Along this section the eastward continuation of the Sella thrust to lower stratigraphic levels can be observed. CD, Cassian Dolomite (Middle Carnian); S, San Cassiano Fm (Middle Carnian); Du, Dürrenstein Dolomite (Upper Carnian); R, Raibl Fm; P, Dolomia Principale (Norian). In the foreground, near Arabba, the Livinè Line (a thrust fault sealed by the San Cassiano Fm, 600-700 m thick to the left and only 150-200 m to the right) is indicated.

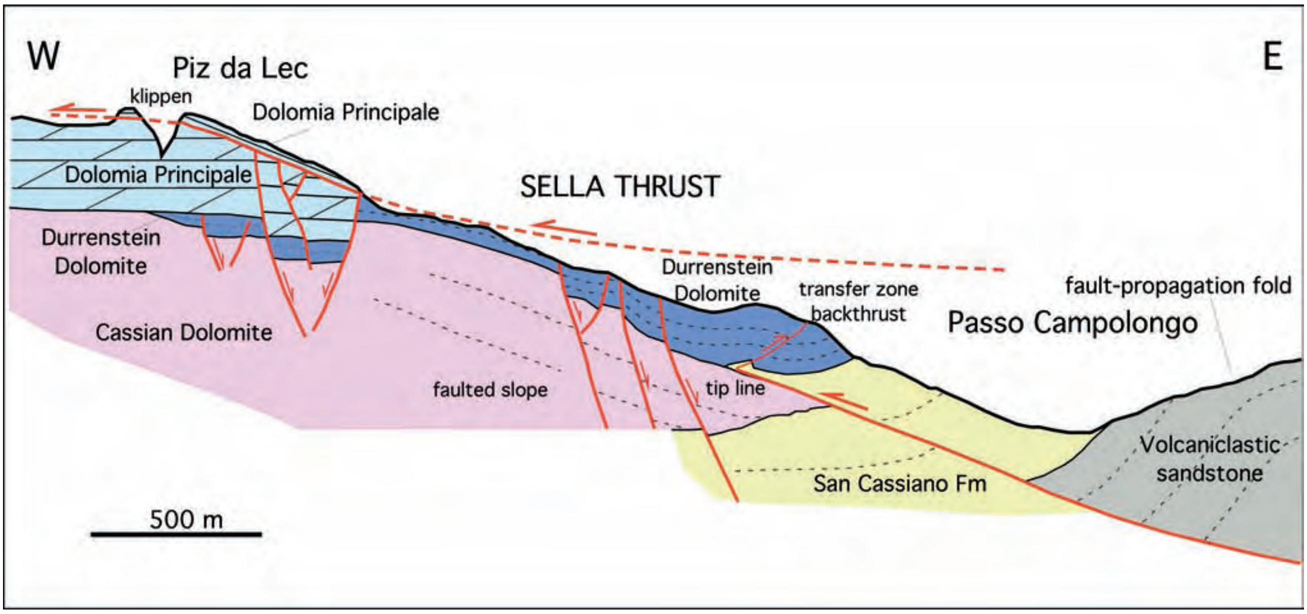


Fig. 4.25 - Geological section of the eastern flank of the Sella Massif. The eastward continuation of the Sella thrust (ramp in the Dolomia Principale and flat at its top) can be observed. Towards the bottom of the section, the thrust plane is partly eroded and crops out again more to the east in the meadows of the Altipiano del Cherz-Pralongià. A blind thrust, however, occurs above the slope of the Carnian carbonate platform (Cassian Dolomite) and is associated to a fault propagation fold. The inclined stratigraphic plane was thus a heterogeneity that controlled the distribution of the shortening. N-S trending synsedimentary extensional faults disrupted the continuity of the slope. They are upper Carnian (syn-Dürrenstein Dolomite) or younger (after Doglioni, 1992).

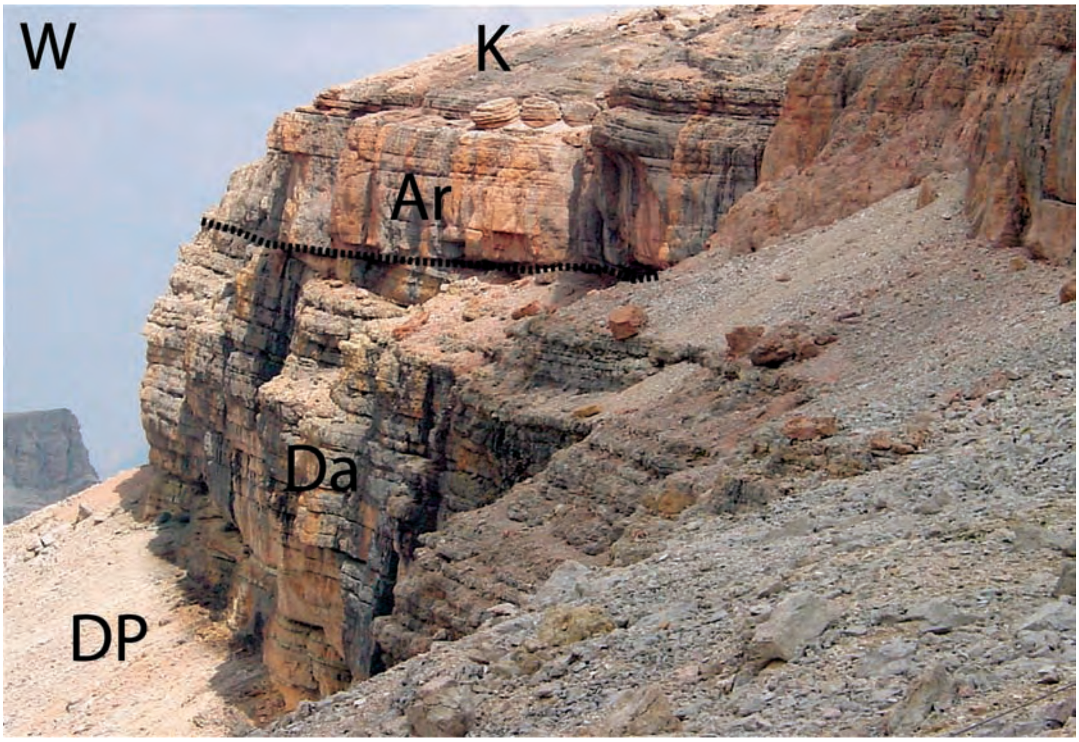


Fig. 4.26 - Angular unconformity between the Middle-Late Jurassic condensed sequence of the Ammonitico Rosso (Ar) and the underlying Rhaetian Dachstein Limestone (Da). DP, Dolomia Principale; K, Puez Marls. At the unconformity occurs a several cm thick hardground. Note the absence of the Liassic Calcari Grigi in this part of the Trento Horst. Moving eastward, the early Jurassic appears with few hundred meters thickness, suggesting synsementary tectonics.

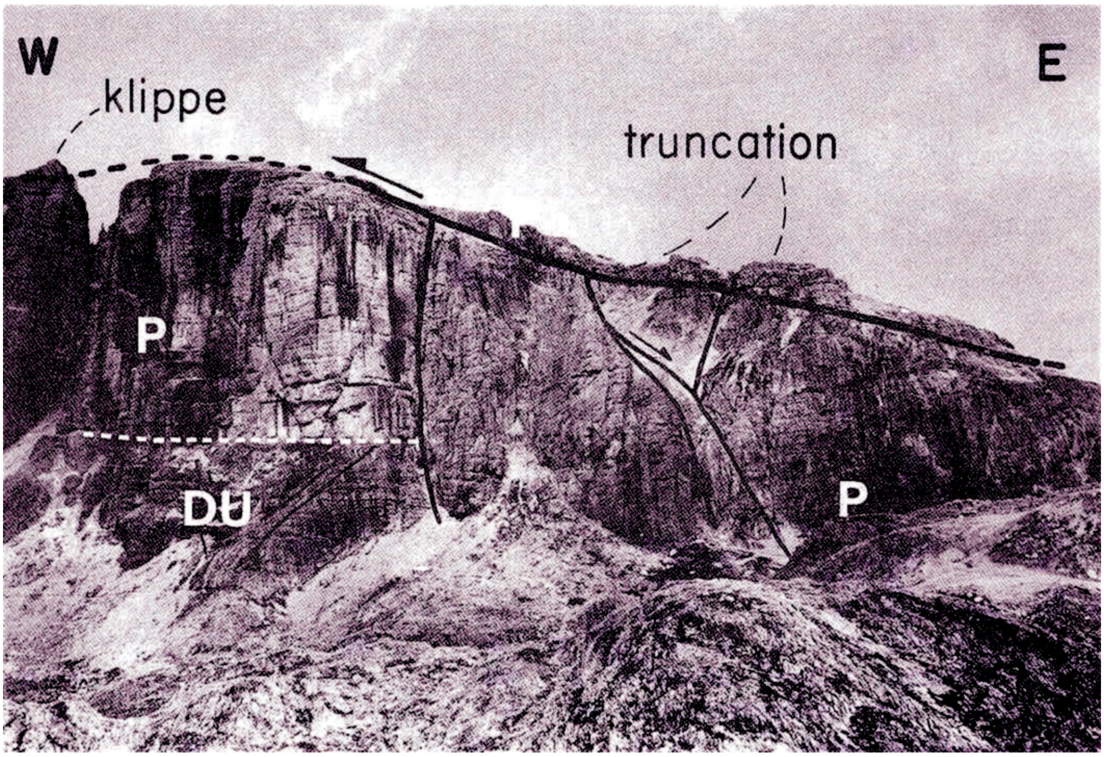


Fig. 4.27 - Detail of the western part of the section of Fig. 4.25. Vallon del Serla, east of Piz Boè. Note the W-vergent thrust with ramp and flat geometry. The dislocation plane cuts N-S trending extensional faults. P, Dolomia Principale; DU, Dürrenstein Dolomite. The hangingwall is made of Dolomia Principale.

Fig. 4.28 - Detail of the central part of the section of Fig. 4.25. The synsedimentary character of the N-S extensional faults is evidenced by the angular unconformities within the Dürrenstein Dolomite (Du). CD, Cassian Dolomite.

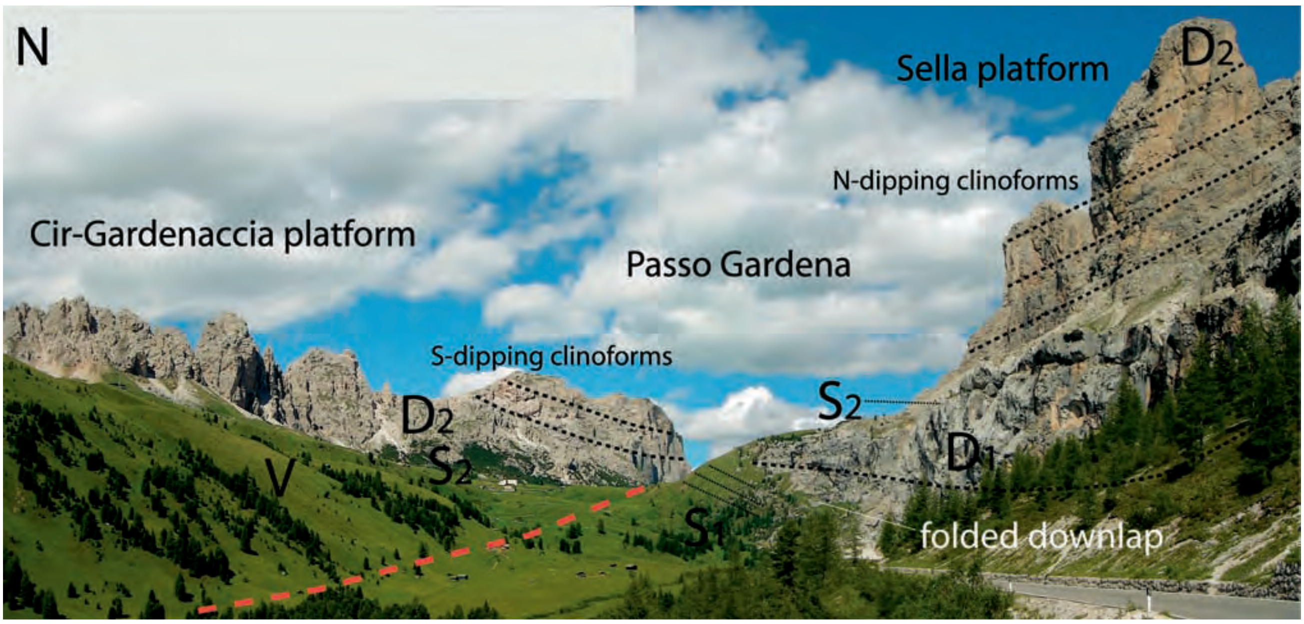


Fig. 4.29 - Two opposite prograding platforms border the Passo Gardena. A fault, possibly with a left-lateral component, runs across the pass. To the south the lower part of the Sella megabreccias are folded and thicker, suggesting a synsedimentary Carnian origin of the deformation since the upper part is undeformed, as shown by the angle between the upper clinoforms and the lower ones. See the interpretation in the next figure. Carnian, D2, Upper Cassian Dolomite; S2 Upper San Cassiano Fm; D1, Lower Cassian Dolomite; S1, Lower San Cassiano Fm; Ladinian, V, volcaniclastic sandstone. Note in the northern side, that V is at the same structural elevation of D1 south of the fault, and the missing (or highly reduced?) D1 and S1.

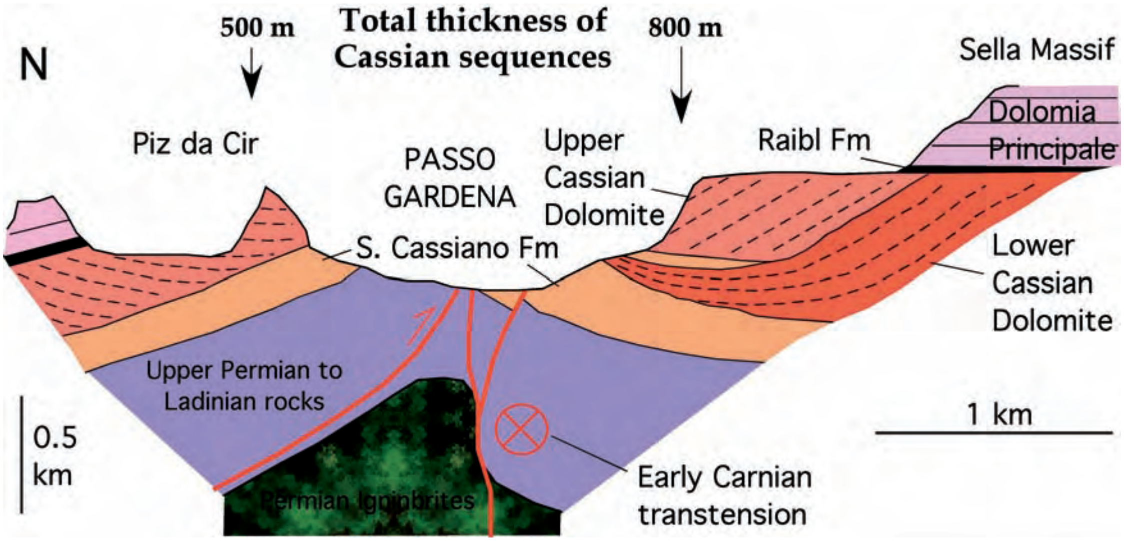


Fig. 4.30 - Geological section of the northern side of the Sella Group, through the Gardena Pass, where two Carnian carbonate platforms converge with their progradation. At the Gardena Pass, a sinistral transtensional fault system, Triassic in age and trending roughly E-W, crops out. The kinematics of the fault system is indicated by slickenlines, attitude of the fault plane and changes of sediment thicknesses left and right of the fault. For example, to the south (right) of the fault, the lower Cassian Dolomite occurs, whereas it is not present to the left. Moreover, the same dolomite is folded syndepositionally in its lower part, near the Passo Gardena Line. A S-vergent Alpine thrust complicates the structure (after Channell & Doglioni, 1994).

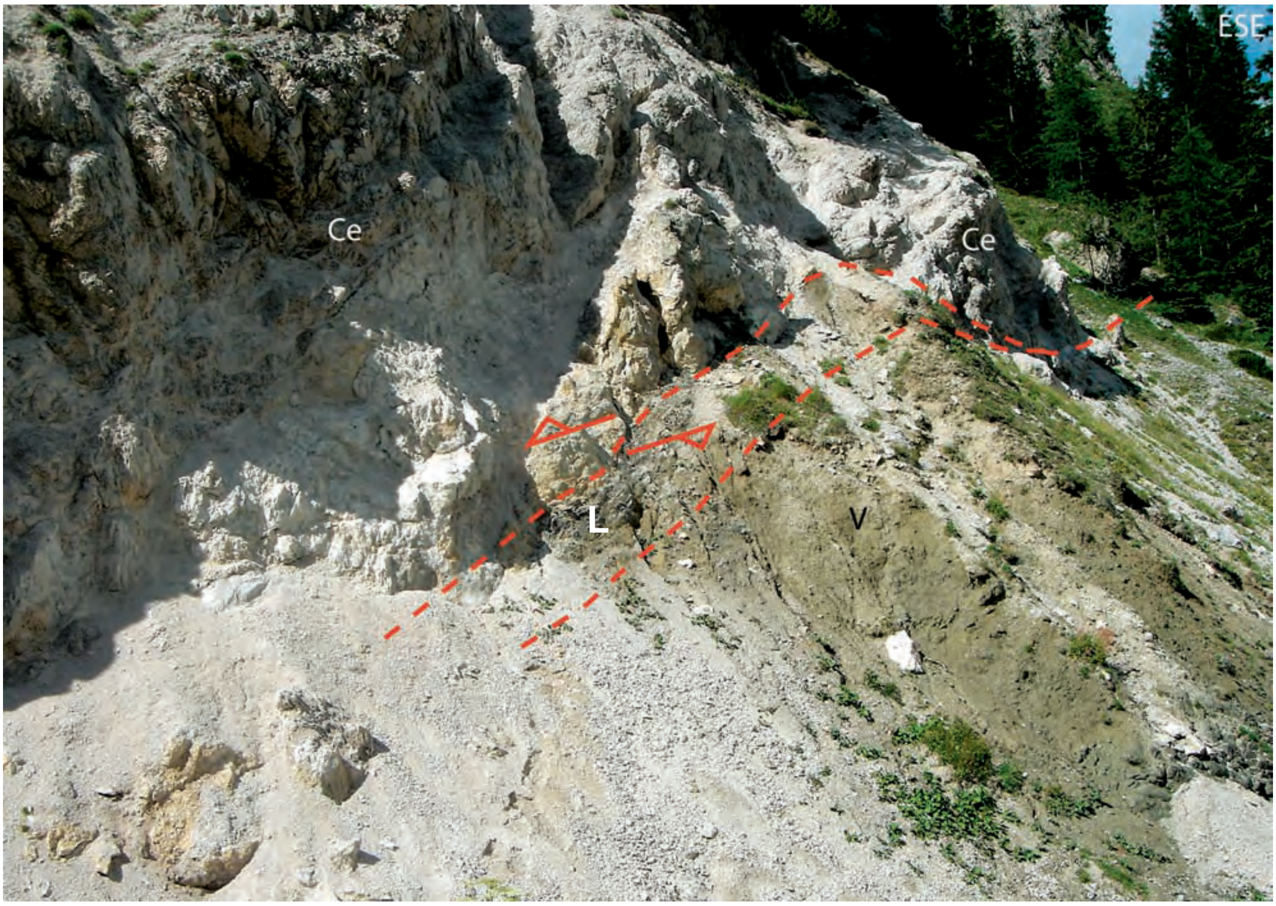


Fig. 4.31 - Outcrop of the Passo Gardena Line, along the road between Corvara and Passo Gardena. Ce, olithoslith of Contrin Fm included in the Ladinian Caotico Eterogeneo; L, Livinallongo Fm, dark marly limestones; V, volcanoclastic sandstones. On the sub-vertical N70°-90°E trending fault plane there is evidence for left-lateral transtensive/transpressive component.